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The Għadira Reserve: Physico-chemical Characteristics of the Pool

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Introduction

The Għadira Reserve is the largest saline marshland in the Maltese Islands. It is a protected bird sanctuary and a review of its development may be found in Sultana (1990) and a more detailed description of the area is given in Borg *et al.* (1990)

This paper will present data on the physico-chemical parameters in the waters of this marsh as recorded from four fixed stations over a period of one year (May 1985 - April 1986). The purpose of this investigation was to provide information to the ecological study of the Għadira pool (Borg *et al.*, 1989) and thus to contribute towards the basic environmental information which is essential for the correct management of such reserved areas.

The present Għadira marsh complex consists of a central pool with a number of small artificial 'islands' *(Figure 1)*. The pool is surrounded by a embankment and a ditch to limit public access to the area. Furthermore, the ditch was designed to collect rainwater and drain it into a freshwater reservoir constructed on the west side of the pool at the farthest side from the sea. This reservoir was to supply the central pool with enough water throughout the year and thereby to prevent its drying up during the summer months (Axell, 1980). The Għadira marsh complex is separated from the sea (Mellieħa Bay) by a road and a narrow sandy beach which together are approximately 100m wide.

Methods

Four sampling stations were selected as indicated in *Figure 1*, namely:

Station 1: Ditch
Station 2: East side of the pool, nearest to the sea
Station 3: South side of the pool
Station 4: Reservoir

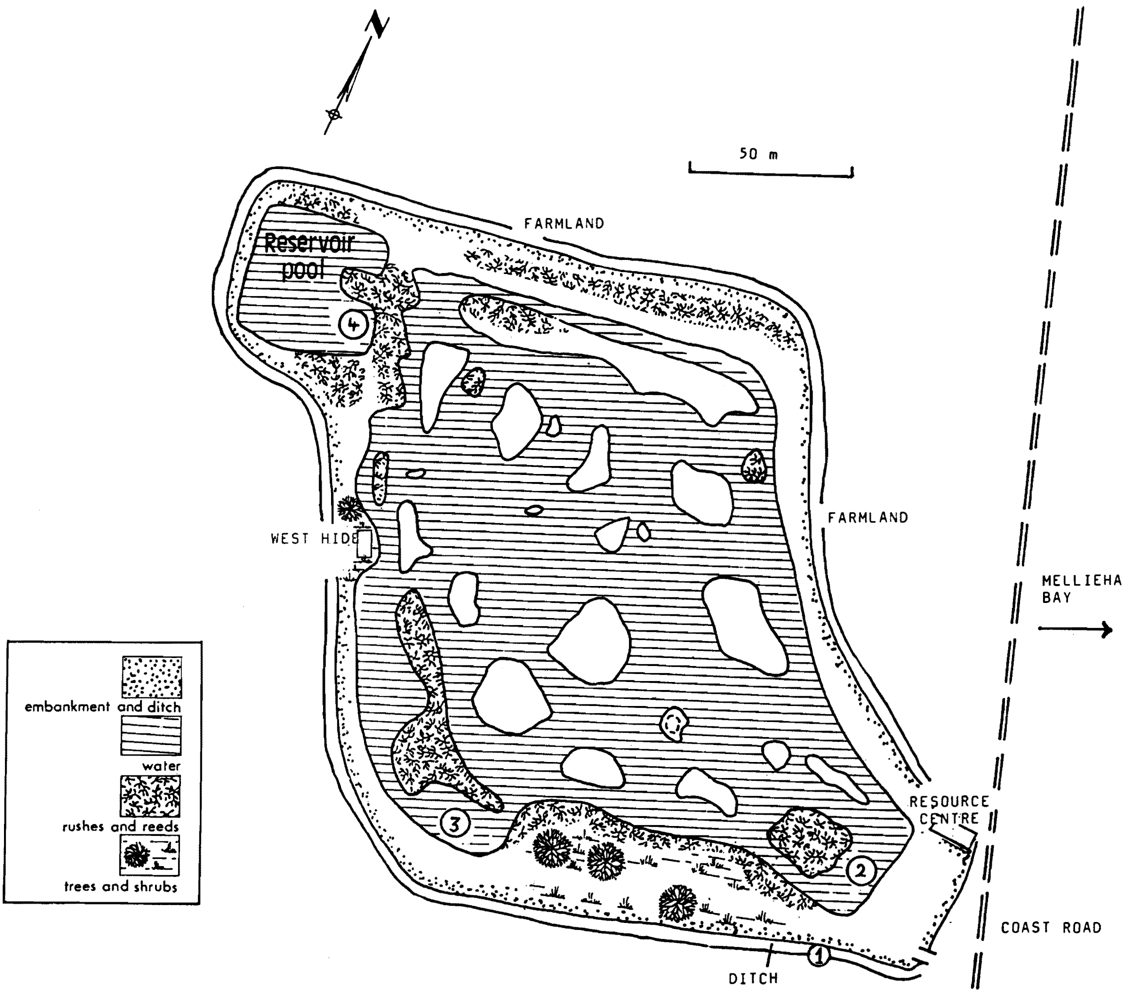

Fig. 1: The Għadira Reserve, showing location of stations for the monitoring of physico-chemical parameters.

We were not permitted to sample at the central region of the pool because of possible interference with bird activity.

At each station, monthly readings of water depth, temperature, salinity (as measured by a salinity/temperature meter Bridge Type M.C. 5) and dissolved oxygen levels (using a YSI Model 54A oxygen meter fitted with a probe model 5739) were taken at the surface and at the bottom. pH was measured using a Griffin field pH meter. Moreover, at each station, water samples were taken from the surface and from the bottom for analysis of suspended matter, chlorophyll *a* content, nitrates, nitrites and dissolved phosphates. These analysis were carried out by methods described by Strickland and Parsons (1972).

Results

The various parameters as measured at the surface at the four different stations from May 1985 to April 1986, are presented graphically in *Figure 2*. These parameters as measured at the

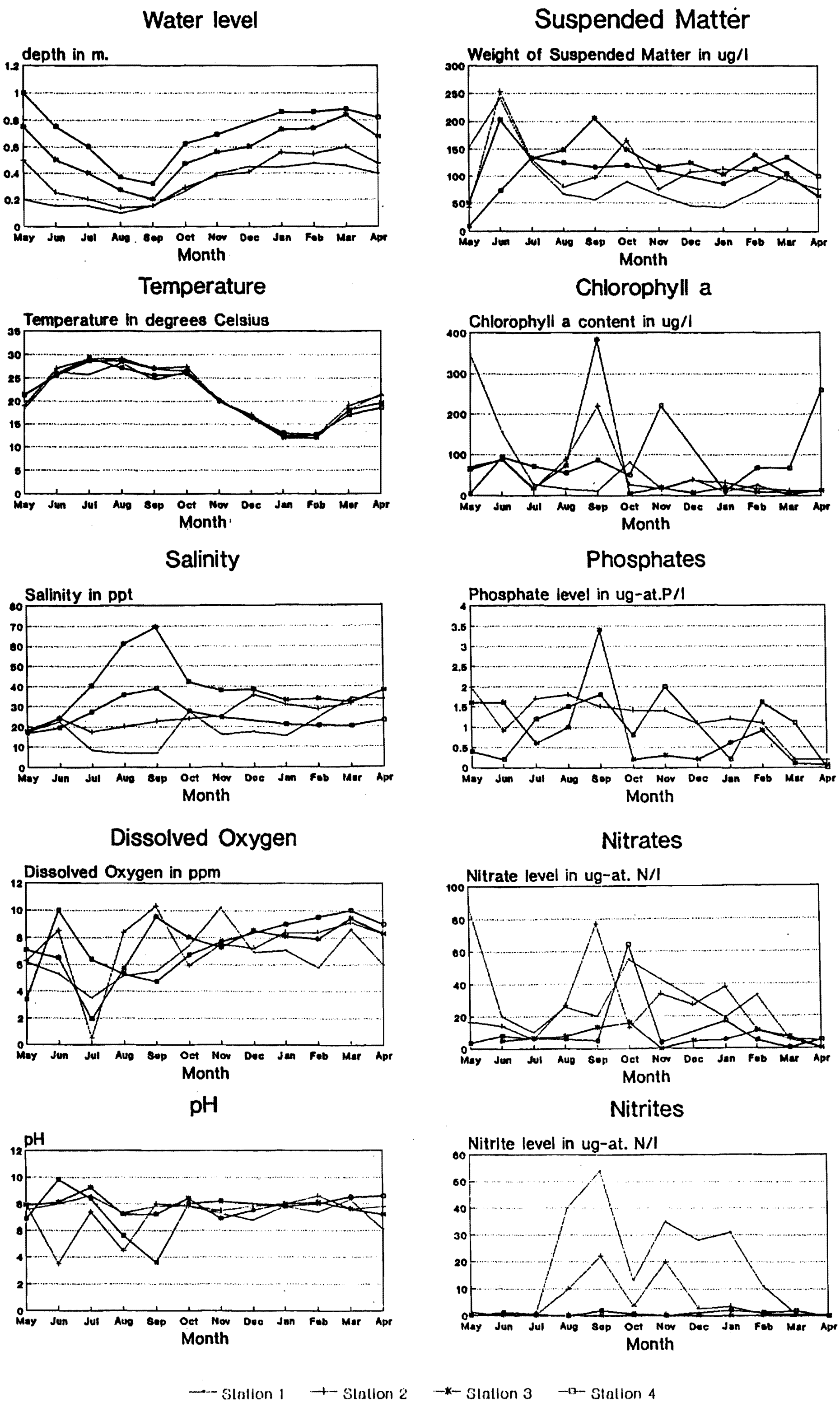

Fig. 2: The Għadira Reserve: Monthly values for the various physico-chemical parameters measured at four different stations.

bottom of each station did not differ significantly than those measured at the surface. This is due to the shallow waters at the four stations sampled, with the mean annual water depths varying from 30 to 70cm. *Table 1,* shows the mean annual values for each parameter at each station, together with the coefficient of variation for each. The latter is expressed as a percentage and shows the relative amount of variation between the different means. For example, while pH shows the smallest range of variation over the period of study, chlorophyll *a* and nutrients show very wide ranges of fluctuations.

The water depth at all four stations remained shallow throughout the year, and this partly explains the wide fluctuations in the other parameters. The lowest depths were recorded in August and September, when evaporation reached a maximum as water temperature peaked at 29 °C. A minimal water temperature of 12 °C was recorded in January/February.

Salinity fluctuations were especially high in *Station 1*, ranging from 7.00 to 33.9 ppt. Annual mean salinities within the pool itself, varied with location, so that while *Station 2,* was found hyposaline (26.3ppt), *Station 3* was hypersaline (38.9ppt). *Station 2* became hypersaline only in April, while *Station 3* remained hypersaline from August to December, with a maximum of 69.4 ppt being recorded in September. This was in fact the highest salinity recorded within the whole area during this study. The reservoir *(Station 4)* was generally brackish with salinities

TABLE 1. Mean values of parameters measured with coefficients of variation.

	Station 1		*Station 2*		*Station 3*		*Station 4*	
Water level (m)	0.3	51%	0.37	44%	0.56	36%	0.7	30%
Temperature (°C)	20.8	27%	21.7	28%	21.3	28%	21.5	30%
Salinity (ppt)	19.2	49%	26.3	25%	38.9	37%	25.0	28%
Oxygen (ppm)	6.5	27%	7.4	33%	7.4	28%	8.1	42%
pH	7.5	2%	7.2	2%	7.8	8%	7.6	22%
Susp. Matter (µg/1)	93.4	61%	112.0	48%	128.0	37%	120.0	36%
Chloro. a (µg/1)	62.0	162%	52.5	113%	58.0	183%	90.0	91%
Phosphates (µg-at P/1)	6.9	124%	1.2	48%	0.88	109%	0.98	71%
Nitrates (µg-at N/1)	29.6	80%	22.5	92%	28.0	261%	11.2	161%
Nitrates (mg-at N/l)	17.9	106%	5.3	148%	0.21	67%	0.89	90%
N/P ratio	14.0	78%	22.6	79%	35.0	142%	38.8	145%

fluctuating from 16.9 ppt in May to a maximum of 39.0 ppt in September.

Oxygen levels were generally high at all stations except in July, when near-anoxic conditions were recorded at *Stations 2* and *3*. These coincided with the warm summer period immediately after a phytoplankton bloom as reported below. Annual pH means were about 7.5 and as would be expected, pH fluctuations were minimal, the only exception being *Stations 2* and *4*, where pH values of 3.5 were sometimes measured.

Levels of total suspended matter as well as of chlorophyll *a* were generally high at all stations throughout the year. Most stations may be described as eutrophic with algal blooms being evident. Primary productivity as measured by chlorophyll *a* levels was minimal for all stations in July, October and January.

Nutrient levels were also high at all stations, with wide fluctuations being reported both for phosphate and nitrate concentrations. Annual mean N/P ration values ranged from 14 to 38.8, but the large coefficient of variations indicate that these mean values are of little significance. In fact, phosphate levels were generally high with N/P ratios being less than 10 for many months at all stations. Nitrite levels were surprisingly high in *Stations 1* and *2*, with maximum values of 40 and 20 µg-at N/1, respectively. Nitrates exceeded nitrate values in *Station 1*, during August September and January indicating strong reducing conditions during these periods.

An attempt was made to model phytoplankton primary productivity as measured by chlorophyll *a* content in terms of the other parameters within the main pool itself *(Stations 2 and 3)*. This was done by multiple regression analysis (Sokal and Rohlf, 1981). The purpose was to estimate and fit a structural model to 'explain' variation in the observations of chlorophyll *a* content, in terms of the other independent variables.

A study of the complete correlation matrices between the various parameters indicated that except for water level, temperature and salinity, most other variables were not well correlated with each other. This means that they may be considered to be independent of each other in most cases and may not be left out of a regression model to explain chlorophyll content. Factor analysis also supported this idea.

The 'best fit' multiple regression equation for *Station 2* was found to be the following:

$$[\mathrm{Chl}\,a] = 209.3 - 2.50\,X_1 - 5.33\,X_3 + 12.31\,X_4 + 5.64\,X_5 - 0.25\,X_6 - 46.37\,X_8 + 2.67\,X_9 - 5.60\,X_{10}$$

and for *Station 3*, this was found to be:

$$[\mathrm{Chl.}\,a] = 144.7 - 3.17\,X_1 - 9.51\,X_4 + 5.43\,X_5 - 1.08\,X_6 + 105.58\,X_8 - 0.48\,X_9 + 181.65\,X_{10}$$

where:

X_1 = water level in cm;
X_3 = salinity in ppt;
X_4 = dissolved oxygen in ppm;
X_5 = pH;
X_6 = suspended matter in µg/1;
X_8 = phosphate level in µg-at P/1;
X_9 = nitrate level in µg-at N/1;
X_{10} = nitrite level in µg-at N/1.

The first regression model accounted for 81.4% of the variance while the second model accounted for 96% of the variance of chlorophyll *a* jointly explained by the rest of the variables. Both models were statistically significant at $P<0.05$.

One must note that any variables left out of the predictor set are not necessarily unimportant. They may simply be correlated with other variables in the predictor set.

Discussion

The Għadira marsh may be considered as a small and highly complex microcosm. It is surrounded on one side by the sea and on the other sides by agricultural land, much of which is intensively cultivated. Three types of boundaries through which this microcosm interacts with the rest of the surrounding environment may therefore be identified. These are:

(a) that *with the atmosphere* (eg. rainfall, fallout of marine aerosol spray carried from the nearby sea and possibly of aerosol droplets of chemicals applied to the surrounding fields);

(b) that *with the bottom sediments* through which seawater may seep through from the nearby bay or through which ground water from the surrounding fields may reach the area;

(c) that *with surrounding surface land* through which agricultural water runoff may reach the marsh.

The relatively small volumes of water within the marsh and the complex nature of its interactions with the surrounding environment result in a wide range of fluctuations of most of the physico-chemical parameters of the pool water as measured in the present study.

A study of Lago Patria which is a small brackish lagoon near Naples (Italy) has similarly shown wide fluctuations in the physico-chemical parameters monitored, with comparable peak values of phosphates, nitrates, nitrites and chlorophyll *a* being reported (De Rosa and Rigillo Troncone, 1981).

The present study has made a contribution towards our understanding of the water budget within the Għadira marsh. During the period under investigation, no water was pumped into or taken from the reservoir *(Station 4)* to be utilised in the main pool. Therefore the input of water into the pool was only through rainfall, seepage and drainage from the surrounding land. Moreover seawater may have reached the pool through the ditch during sea incursions, especially during periods of high wave action. For example, the sudden increase in salinity in the ditch *(Station 1)* in October, occurring after a period of heavy rainfall and rough weather and can only be explained by incursions of seawater into the ditch. Seepage of seawater through the strata of compacted beach sand and soil was most evident during the summer months. Moreover, during these months, loss of water from the main pool resulted in the formation of isolated small pools, such as at *Station 3*, which attained the characteristics of rockpool with salinities higher than 38 ppt for at least six months of the year.

The high nutrient levels recorded in all stations at least during most months is probably due to agricultural run off from the nearby fields. This was confirmed by the fact that after heavy rains in September/October, nitrate contents in the ditch *(Station 1)* reached maximum levels.

Phytoplankton blooms were evident during two periods of the year, namely: May/June and August/September. The May/June algal blooms were apparently triggered by an increase in temperature, since nutrient levels were generally high and non-limiting. This was followed by a period of fast decomposition, with near-anoxic conditions in the main pool. During the subsequent summer phytoplankton bloom, macroalgal blooms of *Cladophora* sp. and *Enteromorpha intestinalis* among others, could also be seen to cover the water surface almost completely, especially in *Stations 2* and *3*.

Moreover, this study has shown, through a multiple regression analysis, that phytoplankton primary productivity in similar habitats is dependent on a large number of physico-chemical parameters which interact in a complex manner. Furthermore, the fact that different models had to be used to explain productivity in two stations within the main Għadira pool indicate that during the periodic drying up of some of its areas, isolated smaller pools are formed, each of which may be considered to be a self-contained microcosm. This further illustrates the complex nature of such small systems which are bordered by agricultural land and the sea.

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